THE ENERGY LOSS OF YOUNG WOMEN DURING THE MUSCULAR ACTIVITY OF LIGHT HOUSEHOLD WORK.

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In the computation of the food requirements of women and children, certain factors have been applied to the standards for men—factors which have long been established and which are based solely upon differences in body-weight. Since the body-weight of the average woman is but 80 per cent. of the body-weight of the average man, it has been assumed that the food requirements of women are in like proportion. The average energy requirement of the resting woman has been found to be actually 17 per cent. less than that of the average man under the same conditions of muscular repose. Furthermore, studies in the Nutrition Laboratory upon the differences in the need for energy of quiet men and women have shown that with complete muscular repose and absence of food in the stomach, men on an average produce 6.2 per cent. more heat than women of the same age, height, and weight.

But food requirements are made up of two factors: (*a*) the food required for the maintenance of the quiet body doing no external work; (*b*) the excess food needed for the accomplishment of the various daily tasks. Dietary allotments, therefore, deal not only with the basal requirements but also with the very considerable excess food required for the multitudinous daily tasks. The variety of mechanical operations and muscular movements incidental thereto which are engaged in by men is very great; ultimately the energy requirements for these different operations should be established. It is popularly considered that the muscular activity of the average woman is much less than that of the average man. This is probably true, but as household work in some form or other still remains a not inconsiderable factor in the muscular activity of most women, exact information as to the energy needs for the performance of the domestic duties of the household is essential for an intelligent computation of the daily requirements of the average woman. These domestic activities consist for the most part of sitting, standing, walking, sewing, sweeping, dusting, washing clothes and dishes, ironing, cooking, bed making, etc. What, then, are the requirements for energy above the basal for these and other activities?

The Nutrition Laboratory, in establishing its long series of basal values for new-born infants, children, and adults, has adhered to the time-consuming method of studying *individuals,* and a decade has been needed to secure this basal information. In the belief that with definitely established basal values, the excess energy required for muscular activity could be studied to greater advantage with groups, and thus *general average* values be obtained more rapidly and possibly with a greater degree of accuracy, a respiration chamber of sufficient size to seat 30 to 40 persons was constructed and its accuracy tested.[1]

This respiration chamber, 5.18 meters long, 3.81 meters wide, and 2.29 meters high, is well ventilated by forcing outdoor air in at one end and withdrawing the chamber air at the other. The special feature of this apparatus is the sampling device. A rotary air impeller discharges air from the chamber into a copper box or wind chest having three circular openings in it, two of these being 10 millimeters in diameter and one 29 millimeters in diameter. The amount of air leaving the wind chest through these three openings is roughly proportional to the area of each opening and is obviously alike for the 10-millimeter openings. Over each of these two openings is placed a can covered with a rubber bathing cap to enclose the discharged air. By means of a supplementary blower, air is withdrawn from each of the sampling cans at exactly the rate at which it is delivered into the can. In actual practice, therefore, the air enters the cans at atmospheric pressure, is immediately withdrawn, forced through containers holding sulphuric acid and soda lime, respectively, and then discharged. By weighing the soda-lime con-

[1] For a detailed description of this chamber, see Benedict, Miles, Roth, and Smith, Carnegie Inst. Wash. Pub. No. 280, 1919, pp. 92 to 119, inclusive.

tainer, the carbon dioxide absorbed from the air passing through the 10-millimeter openings may be quantitatively determined.

The exact proportion of air passing through the 10-millimeter openings was found by admitting a known weight of carbon dioxide to the chamber from a steel bottle of the liquefied gas, and determining the amount of this gas which passed through each opening. In the present apparatus this happens to be exactly 10 per cent. of the total, *i. e.*, 10 per cent. of the air is delivered through each of the 10-millimeter openings and 80 per cent. through the 29-millimeter aperture. The weight of carbon dioxide absorbed in the purifying vessel, corrected for the amount of carbon dioxide contained in the incoming air (a correction obtained by a simple calculation), is therefore exactly one tenth of the total amount produced in the chamber during the experiment, provided no change has taken place in the percentage of carbon dioxide residual in the chamber air. Analyses of the residual air, made with a Haldane apparatus at the beginning and end of the period, give this correction, and the true carbon-dioxide production is thus rapidly determined.

With this respiration chamber, experiments with periods no longer than twenty minutes are perfectly practicable. The determination of the carbon-dioxide production has of itself but little value, but is used for computing the heat production by means of the calorific value of carbon dioxide at an assumed respiratory quotient. Such a method is admittedly not so accurate as the direct measurement of the heat production, or the computation of the heat production from measurements of the oxygen consumption. It is, however, a rapid method and not too costly for determining the approximate heat output of a group of people.

Through the personal interest of Professor Alice F. Blood, several groups of Simmons College undergraduates were interested in the research and volunteered to act as subjects for this series of experiments. The studies were made with over two hundred women. In this research the standard values used for comparison were not obtained under the usual experimental conditions for determining basal metabolism, that is, twelve hours after the last meal and with the subject lying down in complete muscular repose, but to give practical living conditions, they were determined two hours after a very light breakfast and with the degree of repose possible with the subjects sitting quietly, reading. Hence, this standard value or base line should not be confused with true basal minimum metabolism measurements. From past experience, the standard value here used may be estimated to be not far from 10 per cent. higher than the true basal or minimum value.

All of our experiments were made with one or more periods at the beginning, in which the standard value was established for the day under the conditions outlined. Observations were then made of the increment due to reading aloud, singing, sewing, standing quietly, sweeping, dusting, standing up and immediately sitting down, and with the subjects marching in single file around the chamber. These observations are now being extended so as to include many more household activities. The ages, heights, and body-weights of all of the subjects have been recorded. The calculations of the metabolism have been made on the basis of uniform body-weight, as Harris[2] has recently shown that the metabolism per kilogram of body-weight is, with homogeneous material, a satisfactory method of comparison.

Since every experiment contained periods in which the standard metabolism was determined for use as a basal value, a considerable amount of data is available showing the metabolism of the subjects while they were sitting quietly, reading. The results of these quiet periods are given in Table I. as heat output per kilogram of body-weight per hour. In computing these values, we have assumed a respiratory quotient of 0.90, since all of the experiments were made two hours after a light breakfast. The calorific value of carbon dioxide at this respiratory quotient has therefore been used in all of our calculations, namely, 2.785 calories per gram of carbon dioxide. From this series of experiments on twelve different days, embodying twenty-three periods, in which over two hundred women participated, it is seen that the average heat production per kilogram per hour was 1.12 calories. This average figure of 1.12 calories has a specific interest in that it indicates the probable heat production of

[2] Harris and Benedict, Carnegie Inst. Wash. Pub. No. 279, 1919, p. 160.

women sitting quietly under ordinary living conditions with a moderate amount of food in the stomach.

TABLE I.

RESTING METABOLISM OF GROUPS OF YOUNG WOMEN.
(Subjects sitting quietly reading, 2 hours after light breakfast.)

Date.	Number of Women.	Number of Periods.	Heat Output per Kgm. per Hour.
1917			cals.
January 15	20	1	1.16
20	14	1	1.07
April 7	15	1	1.05
14	15	1	1.12
21	23	3	1.12 1.06 1.05
23	18	3	1.11 1.19 1.15
30	20	3	1.13 1.06 1.07
May 5	19	2	1.23 1.12
1918			
March 16	25	3	1.20 1.21 1.18
April 6	25	2	1.18 1.21
April 27	15	1	1.13
May 4	15	2	1.00 0.97
Average	—	—	1.12

The percentage increments in the metabolism due to the various household activities studied are given in Table II. These are arranged in the order of increment in energy requirement. Although perhaps of minor practical importance, it is of physiological interest to note the metabolism necessary for reading aloud. In these experiments the students read in unison either from a standard college text book or from the book of Psalms. Three experiments with twenty-three to twenty-five women, with a total of eight periods, showed increases of 3, 1, and 5 per cent., respectively, with an average of 3 per cent. Frankly, this was rather a surprising observation, for it would be expected that the effort of reading aloud would be measurably greater than here indicated.

The slight increase in metabolism due to reading aloud is of even greater interest when compared to the large increments noted when the subjects were singing. In these experiments the subjects sang from a book of college songs or a standard hymnal used in chapel. In the three experiments with fourteen to twenty women, covering in all four periods, the rather irregular percentages of 17, 34, and 16 were obtained, with an average of 22 per cent., this being

TABLE II.

PERCENTAGE INCREASE IN METABOLISM OF WOMEN DUE TO LIGHT MUSCULAR ACTIVITY.

Occupation.	Number of Women.	Number of Experiments.	Number of Periods.	Increment.	
				In Individual Experiments.	Average.
				p. ct.	p. ct.
Reading aloud	23 to 25	3	8	3 1 5	3
Standing quietly	20	1	1	9	9
Hemming	15	2	2	16 10	13
Singing	14 to 20	3	4	17 34 16	22
Dusting	15 to 19	3	4	126 121 156	134
Sweeping	15	2	4	139 161	150

more than seven times greater than that noted when the subjects were reading aloud.

To determine the increment in the metabolism due to the labor of plain sewing (hemming), two experiments with fifteen women, and covering two periods, gave 16 and 10 per cent., respectively, with an average of 13 per cent. Since in this sitting occupation, the bodies of the subjects remained relatively quiet and the arms alone were moved, it is perhaps not surprising that the increment was no greater.

To throw some light upon the additional energy requirements necessary for maintaining the standing position, one experiment with twenty women with one period was made in which it was found that the extra metabolism required for standing was 9 per cent. above the standard sitting resting metabolism. This agrees reasonably well with values found in this laboratory for subjects in the post-absorptive condition for the differences between sitting and standing.

As a typical household occupation, involving moderate muscular exercise, the metabolism during sweeping was studied in two experiments with fifteen women and covering in all four periods. The increments noted were 139 and 161 per cent., respectively, with an average of 150 per cent. This is somewhat less than the increase due to moderate walking found in the Nutrition Laboratory, which was approximately 250 per cent. above the metabolism with the subjects in the standing position.

Another household occupation studied, involving rather moderate muscular effort, was that of dusting. In these experiments the subjects were required to dust chairs, wiping the rounds and seat, and at a given signal change to the next chair in rotation. One minute was allowed for dusting each chair. Three experiments with four periods with fifteen and nineteen women gave increments above the basal value of 126, 121, and 156 per cent., respectively, with an average of 134 per cent., an increase only slightly less than that noted in the sweeping experiments, namely, 150 per cent.

The increment in energy with two other muscular activities was studied in this series of experiments but the results are not included in Table II. The muscular work of standing up and sitting down enters into a relatively large number of the daily activities and a special study of this operation was made in that the subjects while sitting quietly in a chair were, on a given signal, required to stand up, remain standing one second, and then immediately seat themselves. This routine was carried out approximately once every minute during the period. In this particular series, it seemed best to compute the increments not as a percentage above basal but as the actual increase in energy for standing up and sitting down per movement and per individual. Two experiments with eighteen and twenty women, covering a total of three periods, gave values of 0.31 and 0.32 calorie, respectively, averaging 0.32 calorie. It thus appears that with young women an energy expenditure of approxiately one third calorie is required for the activity of standing up and sitting down.

On one date, April 6, 1918, a group of twenty-five young women marched slowly about the respiration chamber for twenty-five minutes. The distance walked in going around the chamber once was forty-five feet; this was accomplished about fifty-three times in twenty-five minutes, the exact total distance walked being 2,356 feet. On that particular day the standard value found and used for the base line was 1.20 calories per kilogram per hour. During the walking the heat output was 2.44 calories per kilogram per hour, or an increment over the standard value of 1.24 calories per kilogram per hour. The rate of walking was 1.08 miles an hour and the average weight of the subjects fifty-four kilograms, from which it is readily computed that at this very slow rate of walking the energy above basal required for transporting the body was sixty-two calories per mile. While very few of the experiments on walking made in the Nutrition Laboratory employed so slow a rate of walking as this, many of our observations with slightly faster rates give values from 40 to 60 calories per mile although usually with men, with consequently somewhat higher body-weights. Too little evidence is thus available to indicate whether or not walking at so slow a rate is performed on a distinctly uneconomical basis. The value is not far from that commonly quoted from German sources for the energy required in walking one mile at a moderate rate.

The method used in this research seems to be well founded and applicable to such study. An extension of these observations is planned to include not only women and children, but also men engaged in various activities, these studies forming a part of the general study of muscular work now in progress at the Nutrition Laboratory.

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